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ANNUAL FLOOD DEATH STATISTICS PER STATE PER CAPITA FOR THE UNITED STATES AND PUERTO RICO DURING THE PERIOD 1959-1991

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I. INTRODUCTION

The purpose of this study was to determine annual flood deaths per state per capita. A ranking was calculated with top states highlighted as areas where flood and flash flood education and associated resource allocations might be needed. Historically, flood fatalities have involved only one or two victims and have consequently generated less attention from the media than a significant tornado or hurricane. Therefore, the need for flood resource allocation may not be widely understood outside the scientific community.

Liles (1989) conducted a study of lightning deaths per state per capita which contained surprising results. While Florida, North Carolina, and Texas were the top three states in annual lightning deaths, New Mexico, Wyoming, and Arkansas were the top three states in per capita lightning deaths. These results have been used to increase lightning awareness in New Mexico, among others.

It has long been known that flooding and flash flooding account for the greatest percentage of weather related casualties every year in the United States. By revealing high risk areas within the country, a more concentrated effort for flood and flash flood preparedness and education activities could be made. While it is understood that floods can occur anywhere, a greater percentage of resources should be allocated for high incidence areas. The aging earthen dam system in place across the nation should also be taken into account when considering the distribution of these resources.

II. METHODOLOGY

The information source for this study was *Storm Data* magazine (NOAA 1991). *Storm Data* is a publication of the National Climatic Data Center (NCDC) in Asheville, North Carolina. The magazine consists of monthly reports from each state of what are considered to be significant weather events. Data are compiled from a variety of sources ranging from National Weather Service Forecast Offices to the National Severe Storms Forecast Center in Kansas City, Missouri. State summaries are prepared and sent to NCDC, which publishes the magazine. Information included in *Storm Data* are tornadoes, hurricanes, severe thunderstorms, hail events, wind events, freezing rain and snow events, and flood and flash flood events.

For the purposes of this study, flood and flash flood-related deaths were considered one and the same. It became apparent soon after the research began that certain criteria needed to be set for a death to be considered flood-caused. This was due to repeated inconsistencies within *Storm Data*, especially before the mid-1970s.

Auto accidents resulting from reduced visibilities or slick streets due to heavy rain do not meet the criteria for a flood or flash flood death. There were numerous cases, however, where such events were erroneously included in the flood death count in *Storm Data.*

Hurricane-related deaths were not counted as flood deaths even if flooding led to the fatality. These casualties were tallied as hurricane deaths as defined in *Storm Data.* There were events where moisture from a dissipated tropical cyclone caused excessive rainfall leading to flooding. In these cases, fatalities were included in the flood count. This, too, was consistent with *Storm Data.*

Mudslides were perhaps the most difficult events to decipher. For purposes of this study, any rock or mud slide caused by excessive rainfall was considered a flood event if inordinate amounts of water accompanied the slide. This would differ from slides set off by temperature contrasts or earthquakes, among other reasons. Deaths resulting from snow slides and avalanches were not included in the overall count.

With these criteria established, the task of reading each *Storm Data* issue from cover to cover for the study period, January 1, 1959, through December 31, 1991, was undertaken. For every death credited in *Storm Data*, the description, if given, was used to determine if the criteria were met. Flood death totals were logged for each state for each year, and totals for all years were summed.

Calculations were then made to determine which states had the most flood-related deaths per year per capita. This figure was arrived upon by adding Census Bureau statistics for each state for the years 1960, 1970, 1980, and 1990, then dividing by four. The per capita figures are expressed in terms of flood deaths per one million people and were calculated for each state and the commonwealth of Puerto Rico. A decade by decade breakdown might reveal per capita trends and will be addressed in another study.

Median (most likely) and mode (most frequent) statistics were calculated to determine a more reliable number to use when anticipating annual per capita flood deaths for each state. Only one state (Texas with 5 and 9) had a mode, while 18 of the 50 states (plus Puerto Rico) had a median. These findings further identify the unpredictability of annual flood deaths on which each state can rely. Like hurricanes and tornadoes, many years can go by without the occurrence of an event. Just one event, however, can produce the disastrous results which education, preparedness, and awareness efforts strive to reduce.

III. RESULTS

Fig. 1 displays the total flood-related deaths, as determined above, for the United States from 1959 through 1991. Additionally, comparisons with *Storm Data* are shown for the study period and for the 20-year period, 1972-1991. Total flood-caused deaths for the United States and Puerto Rico were 3934 for the period January 1, 1959, through December 31, 1991. *Storm Data* figures for the same period account for 4441 deaths—a difference of 507, or 12% more deaths. Flood death totals for the 33-year period amount to 119 per year as calculated from this

study, while totals from *Storm Data* account for 135 deaths per year. Findings for the 20-year period, 1972 through 1991, show annual flood-related deaths numbering 135 according to this study, while *Storm Data* figures claim an average total of 146 lives per year. Lightning (the second highest weather-related killer in the United States) for the same 20-year period accounts for about 80 deaths annually.

Mountainous regions do seem more prone to significant flash flood events than flatlands. Fig. 2 is a ranking of annual per capita flood deaths per state. Fig. 3 is a graphical representation of the top 20 ranking states. Individual states of note include South Dakota—the number one ranking state in flood deaths per year per capita. The findings are quite misleading in this case. One event accounted for 99% of all flood deaths in the state. The Rapid City flood of 1972 resulted in 242 casualties. This compares with 245 flood-related deaths in the 33 years of the study. Therefore, with a single catastrophe, South Dakota leads the nation in per capita flood deaths per year. Had the event occurred outside the time frame of this study, South Dakota would rank 43rd. It should be noted, though, that while South Dakota is considered a Plains state, the flood occurred over the rugged Black Hills area.

Puerto Rico ranks second nationally with an average of 4.77 deaths per year per capita. While the island does regularly experience flood events resulting in deaths, Puerto Rico has recorded two especially catastrophic events where over 100 people perished. In fact, 63% of Puerto Rico's flood deaths have occurred in the years 1960 and 1985. However, the mountainous landscape of the island and its position relative to tropical disturbances and stalling fronts makes Puerto Rico vulnerable to significant flood and landslide events, which justifies a vigorous disaster preparedness and education program.

Texas, ranking third nationally in per capita flood deaths per year, was remarkably consistent from year to year in terms of flood or flash flood events. In fact, at least one fatality was reported in each year. Double digit casualties were recorded in 64% of the years of the study. This consistency is the most clear-cut of all the states. The two greatest annual death amounts account for only 15% of the total casualty count for the state. Findings suggest a probability of nearly 100% for flood fatalities to occur in Texas in a given year.

In Colorado, which ranks fourth nationally, 77% of all flood deaths during the period of this study occurred as a consequence of the Big Thompson Canyon flash flood. Had it not been for this event, Colorado would rank 20th. However, it should be noted that a mountainous state susceptible to thunderstorms will remain vulnerable to catastrophic flood events. This is especially true in Colorado because of its rugged terrain, numerous canyons, and increasing number of recreationalists who flock to the area each year.

Similar to Colorado, Montana, which ranks fifth in per capita deaths per year, experienced a great number of deaths during one event. A 1964 dam break related to heavy rain resulted in 34 deaths, which is 81% of Montana's 33-year flood death total. The fact that Montana is sparsely populated is a limiting factor to floods actually claiming lives. However, like Colorado, Montana does enjoy its share of recreationalists during thunderstorm season, making it and those people vulnerable to significant flood events.

Five of the top ten ranking states are in the mountainous West (Fig. 4). A contributing factor to the high rankings for the region may be sparse population increasing the per capita potential. More likely, however, high incidence of per capita flood deaths per year is a function of the terrain and its lure to outdoors people.

Similarly, six of the top 20 states share borders with the southern Appalachian Mountains (Fig. 5). Again, relatively small populations may contribute to higher per capita figures, but data suggest that flash floods and floods occur regularly in the region with isolated catastrophes occurring as well.

Figs. 6-9 show graphical relationships for each state in the Western Region, Southern Region, Central Region, and Eastern Region of the National Weather Service.

IV. CONCLUSIONS AND RECOMMENDATIONS

Data from this study show that five of the top ten ranking states are in the mountainous West. Six states which have borders along the southern Appalachian Mountains ranked in the top 20 of the study. Consequently, preparedness activities for these high ranking states should incorporate findings from this research. Eighth-ranking New Mexico, for example, already incorporates an annual flash flood and lightning awareness week and has done so since 1989. This type of educational activity would likely be beneficial for the top 20 to 25 states in the study.

Descriptions of flash flood and flood events in *Storm Data* proved most useful in determining whether or not a death was flood-related. For example, when searching *Storm Data*, an event titled "Heavy Rain and Flooding" with two deaths attributed to the event may not have necessarily clarified whether the deaths were caused by flooding. In most cases the paragraph following the heading became the determining factor in whether or not to include the death(s) in the total. It was noted that descriptions became much more thorough with time. As a result, the data became much more reliable. In the case of injuries associated with flash floods and floods, rather poor statistical data were found so no reliable study could be made.

It is recommended, therefore, that those who take part in compiling the data which ultimately end up in *Storm Data* continue to do so with accuracy and thoroughness. Consequently, future studies based on statistics from *Storm Data* will remain reliable.

It is also suggested that a more definitive set of criteria be established for what constitutes a flood or flash flood death. Ambiguity abounds in meteorology, and the controversy surrounding direct and indirect weather-related deaths has been ongoing for over 20 years at least. New revisions will attempt to solve the problem regarding flood deaths; however, human judgement will continue to be needed and should be done with care. This will result in the most reliable data in the area of flood fatalities which are the leading weather-related cause of death in the United States. In the area of tornado injuries and fatalities, it is noted that strict definitions have resulted in very reliable data for an extended period of time. A more definitive flood death definition would enable researchers to go back through the era of poor flood death statistics

(mainly before the middle 1970s) and "clean up" these figures. The results of this study which totalled 3934 flood deaths from 1959 through 1991 are proof of a need for this. *Storm Data* statistics totalled 4441 for the same period. The difference of 507 deaths amounts to a 12% difference in flood deaths for the 33 year period.

Results from this study and intuitive thinking suggest that mountainous terrain is much more vulnerable to ***significant*** flash floods than lowlands, which seem prone to more general river flooding. Future studies should concentrate on more clearly showing this relationship and determining which is more costly in terms of lives and property.

It seems quite apparent that many flood victims die as a result of poor decision making, due in great part to ignorance of safety rules. Educational programs directed specially, but not solely, toward children should be devised and distributed widely, particularly in flood or flash flood-prone areas. Just as great attention is paid to tornado and hurricane safety and education in the Midwest and Gulf Coast states, among others, so, too, should a concerted effort be made to educate people in flood-prone areas of the United States. In fact, of monies distributed for flood and flash flood education, awareness, and preparedness, the greatest percentage should be concentrated on high incidence areas. That way more value for educational dollars can be attained.

One can argue that education will not save the life of the person who stubbornly defies road barricades or home evacuation orders, or is otherwise careless about personal safety. However, those people who find themselves in a flood situation with a critical decision to make, and simply do not know better, are the ones who ***may*** be educated and consequently saved from danger. It is through increased education, awareness, and preparedness programs, that lives are be saved.

V. ACKNOWLEDGEMENTS

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ANNUAL FLOOD-RELATED DEATHS FOR THE UNITED STATES 1959-1991

YEAR	FLOOD DEATHS (AUTHOR'S RESULTS)	FLOOD DEATHS (STORM DATA FIGURES)
1959	54	25
1960	148	169
1961	73	93
1962	48	53
1963	42	41
1964	115	142
1965	149	188
1966	66	56
1967	45	53
1968	48	57
1969	306	445
1970	79	131
1971	68	68
1972	421	555
1973	124	178
1974	101	111
1975	125	127
1976	201	193
1977	196	210
1978	143	125
1979	131	121
1980	69	82
1981	85	84
1982	120	155
1983	92	204
1984	79	126
1985	307	166
1986	89	94
1987	75	70
1988	33	31
1989	100	85
1990	142	142
1991	60	61
33 YEAR TOTALS	3934	4441
DEATHS PER YEAR	119	135
20-YEAR AVERAGE (1972-1991)	135	146

Figure 1.

RANKINGS	STATES	ANNUAL PER CAPITA DEATHS	33 YEAR TOTALS
1.	SOUTH DAKOTA	10.75	245
2.	PUERTO RICO	4.77	466
3.	TEXAS	3.09	530
4.	COLORADO	2.42	203
5.	MONTANA	1.72	42
6.	WEST VIRGINIA	1.71	104
7.	NEVADA	1.64	38
8.	NEW MEXICO	1.47	58
9.	VIRGINIA	1.35	224
10.	ARIZONA	1.22	95
11.	HAWAII	1.15	33
12.	GEORGIA	1.14	77
13.	WYOMING	1.05	14
14.	VERMONT	0.88	14
15.	KENTUCKY	0.86	96
16T	ARKANSAS	0.81	56
16T	OKLAHOMA	0.81	74
18.	TENNESSEE	0.79	110
19.	OREGON	0.64	49
20T	CONNECTICUT	0.53	10
20T	MISSOURI	0.53	83
20T	PENNSYLVANIA	0.53	205
23T	LOUISIANA	0.48	60
23T	SOUTH CAROLINA	0.48	46
25.	KANSAS	0.47	36
26T	ALABAMA	0.46	56
26T	MARYLAND	0.46	59
28T	MISSISSIPPI	0.45	35
28T	UTAH	0.45	19
30.	ALASKA	0.41	5
31.	NORTH DAKOTA	0.38	8
32T	IOWA	0.35	33
32T	OHIO	0.35	120
34.	CALIFORNIA	0.32	235
35.	MINNESOTA	0.29	38
36T	NORTH CAROLINA	0.25	46
36T	WASHINGTON	0.25	31
38.	MAINE	0.22	8
39T	NEW HAMPSHIRE	0.21	6
39T	NEW JERSEY	0.21	49
41.	INDIANA	0.17	29
42.	NEBRASKA	0.16	8
43.	DELAWARE	0.12	12
44T	ILLINOIS	0.11	40
44T	NEW YORK	0.11	63
44T	WISCONSIN	0.11	16
47T	FLORIDA	0.08	23
47T	MICHIGAN	0.08	24
49.	IDAHO	0.04	1
50.	MASSACHUSETTS	0.01	2
51.	RHODE ISLAND	0.00	0

Figure 2.

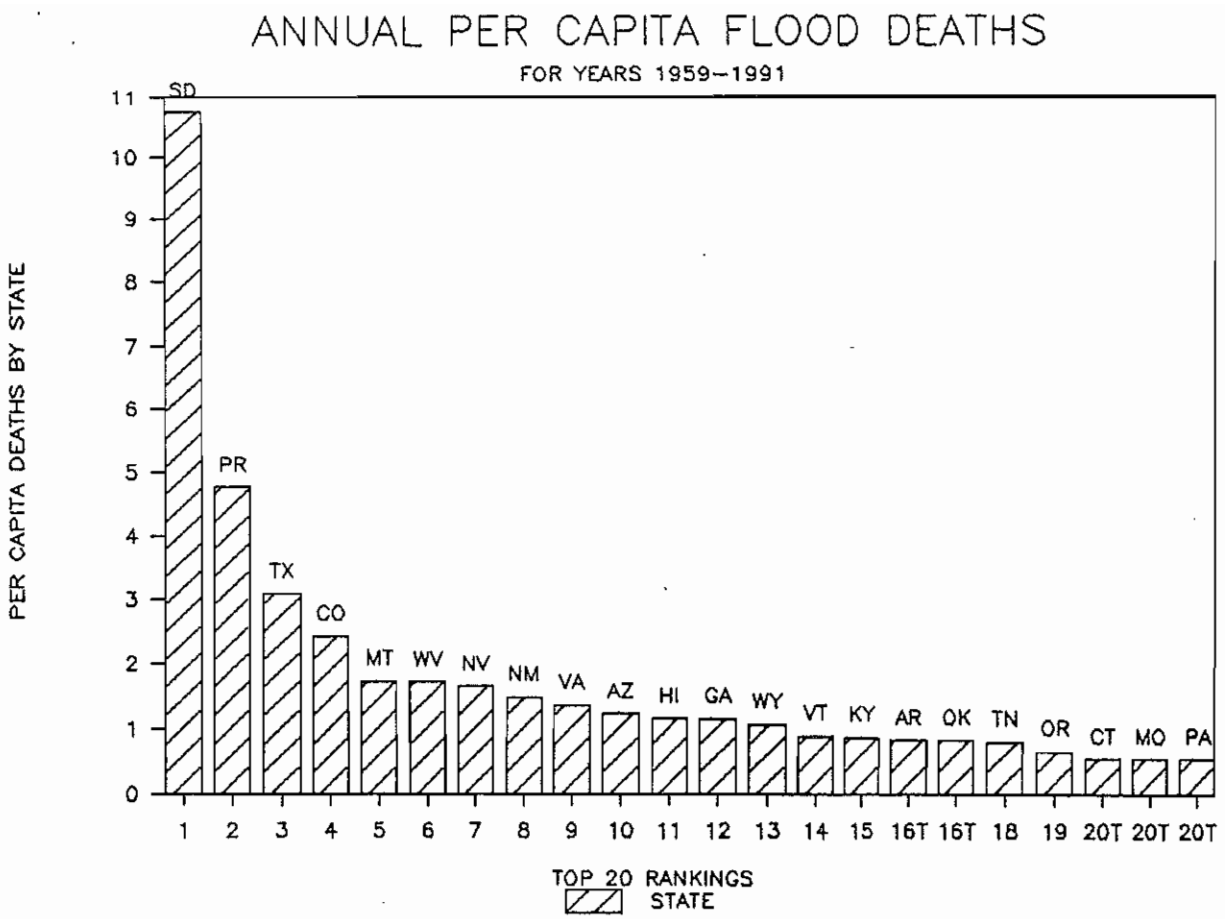

Figure 3.

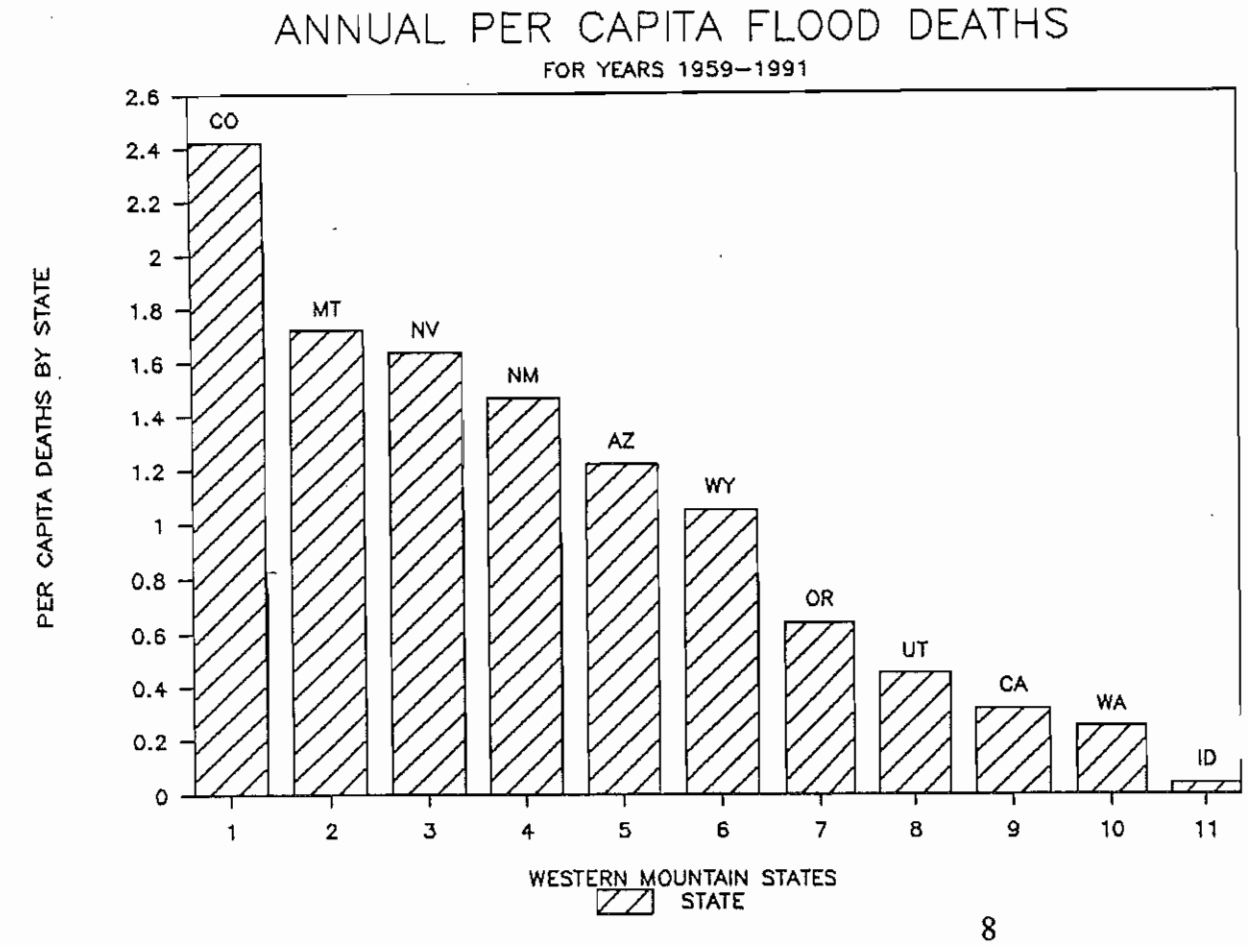

Figure 4.

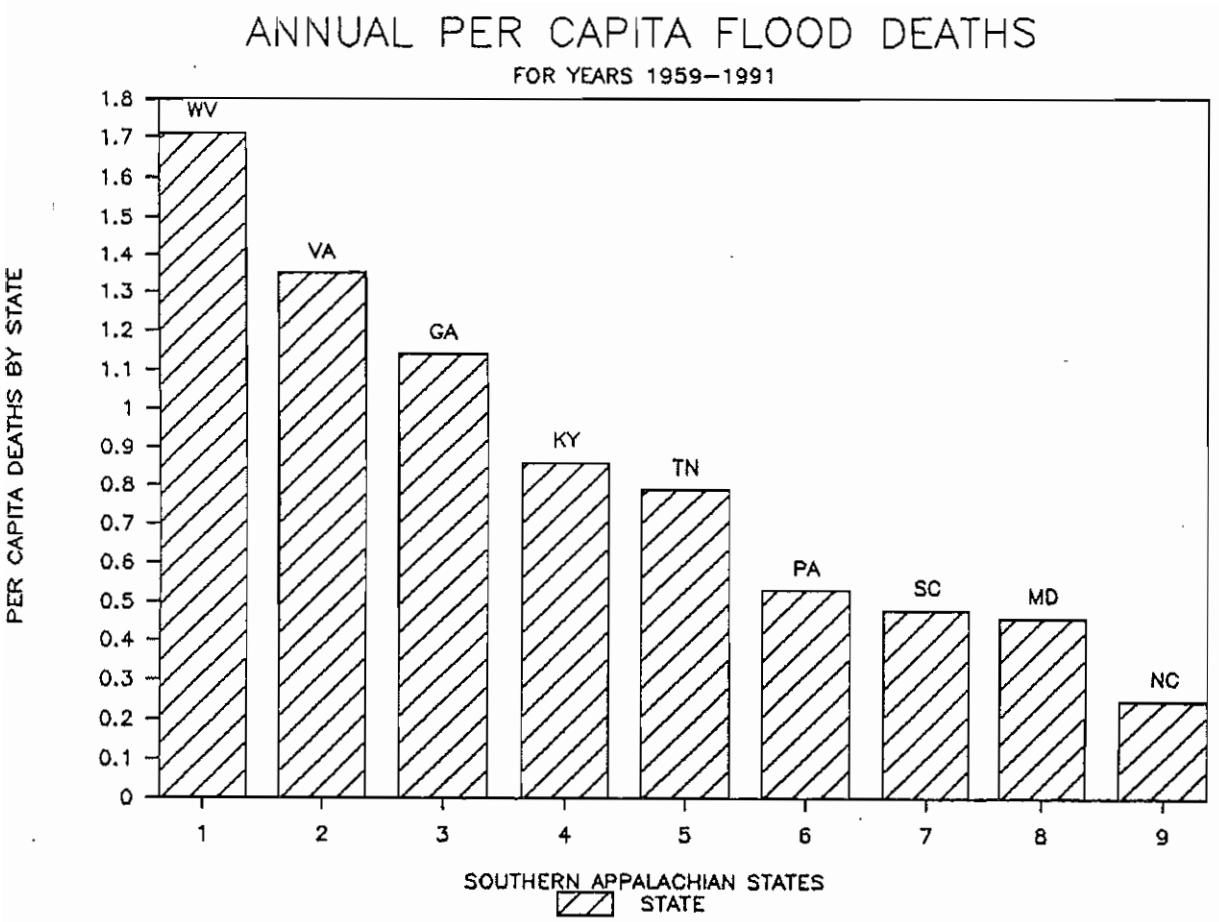

Figure 5.

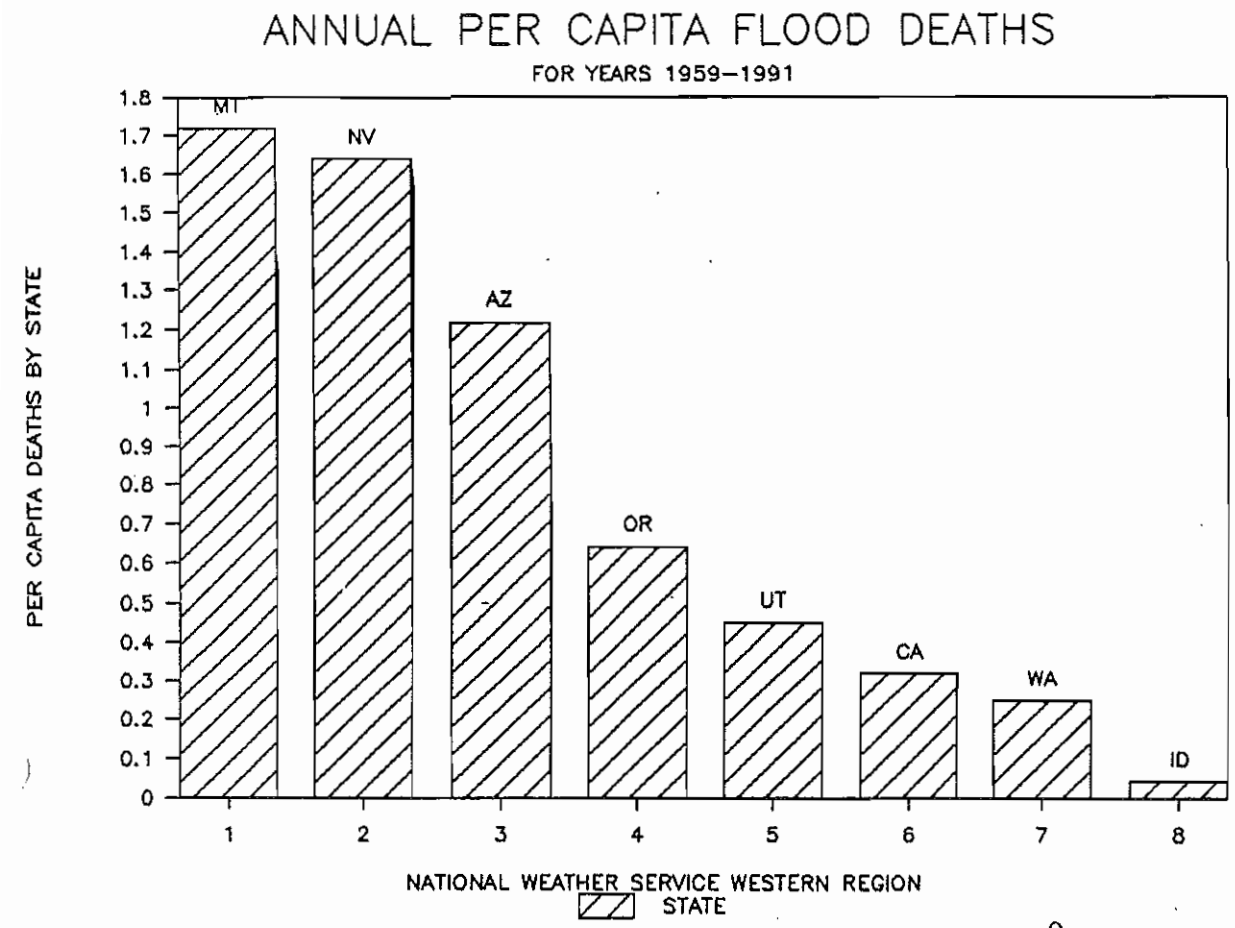

Figure 6.

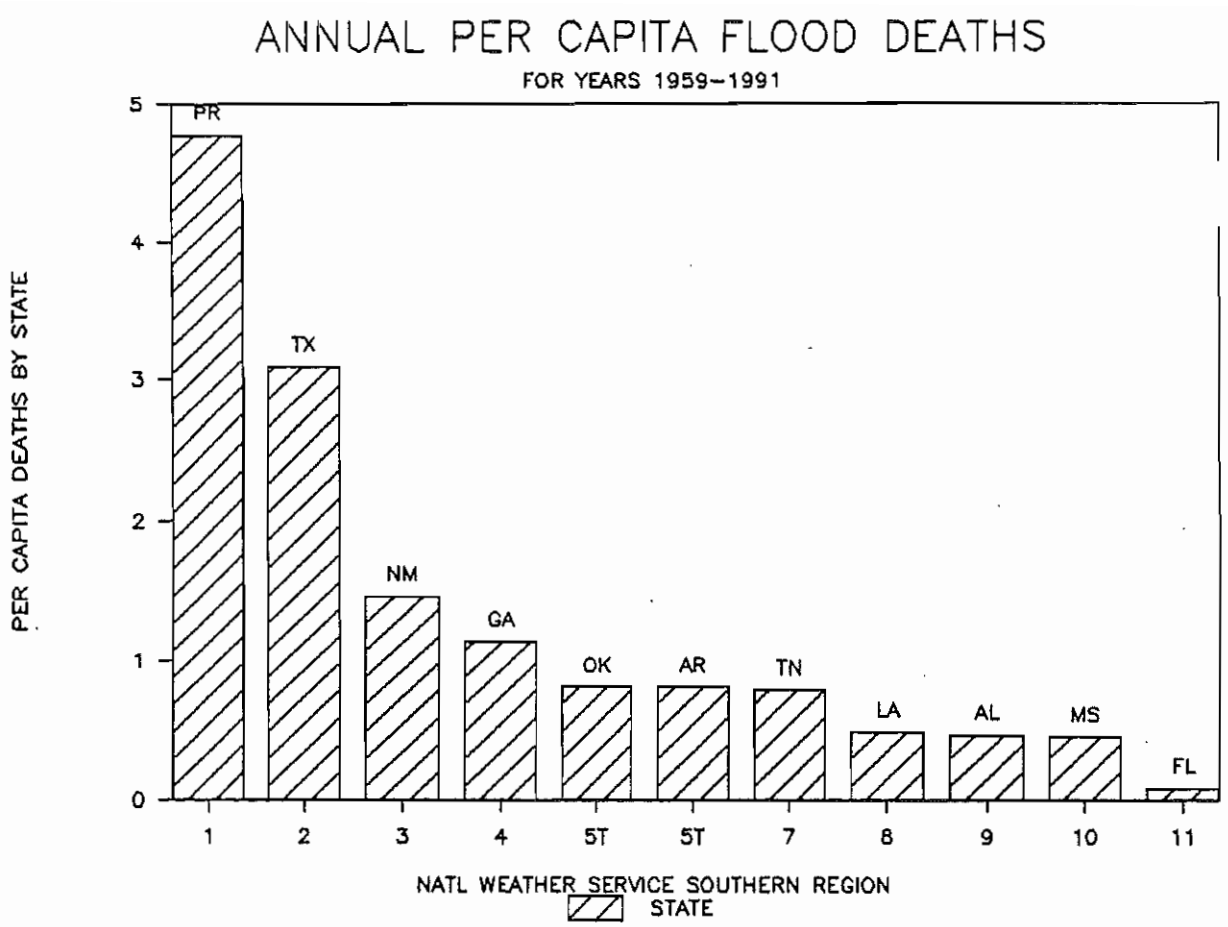

Figure 7.

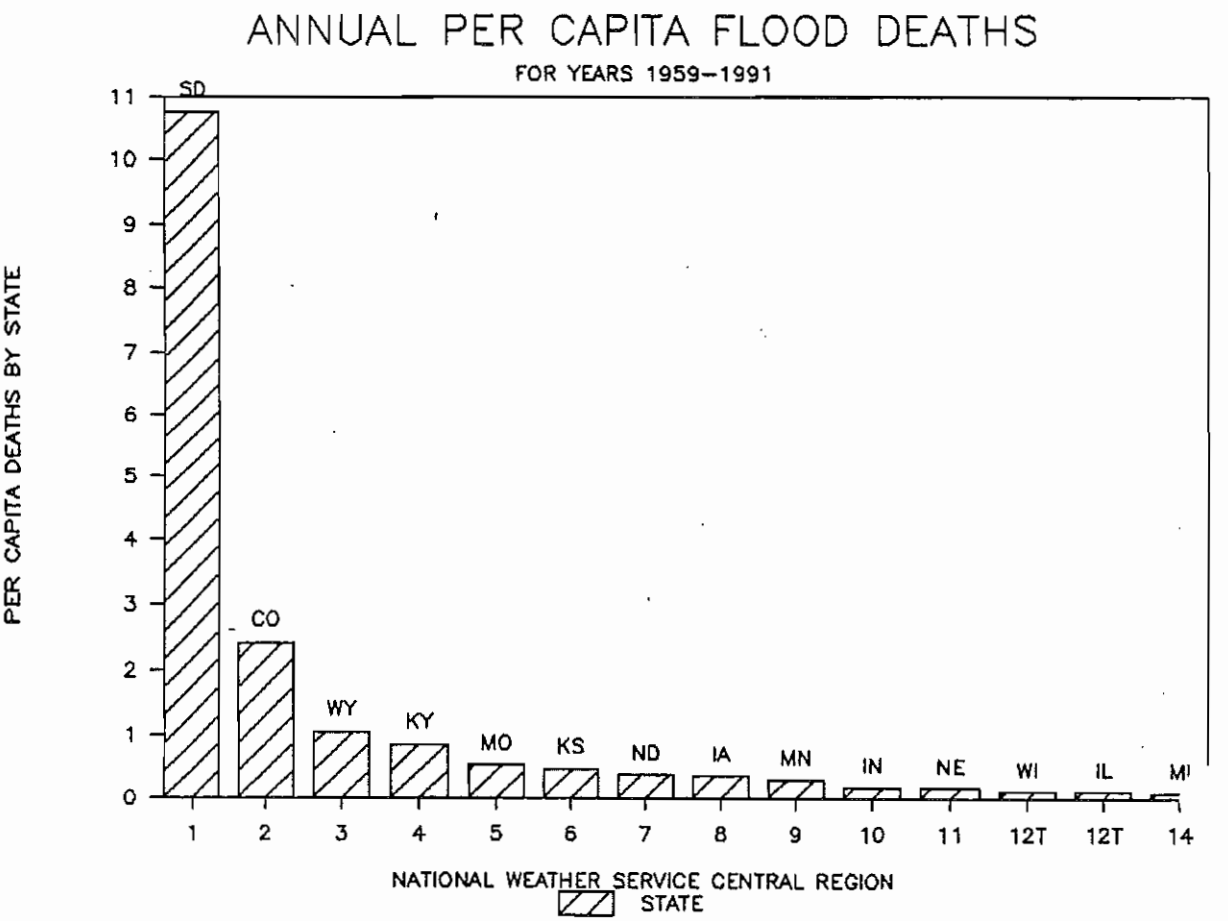

Figure 8.

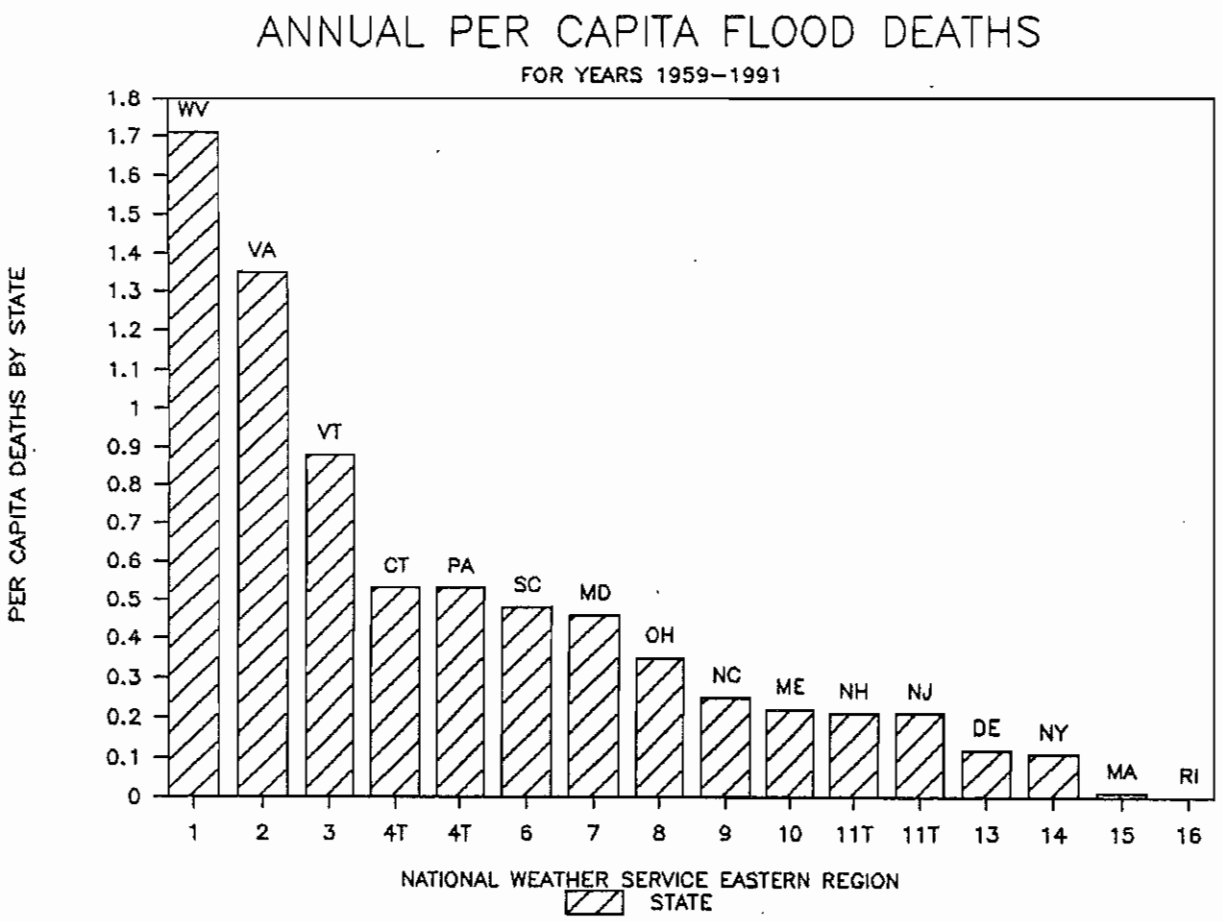
ANNUAL PER CAPITA FLOOD DEATHS
FOR YEARS 1959–1991
PER CAPITA DEATHS BY STATE
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
WV
VA
VT
CT
PA
SC
MD
OH
NC
ME
NH
NJ
DE
NY
MA
RI
1
2
3
4T
4T
6
7
8
9
10
11T
11T
13
14
15
16
NATIONAL WEATHER SERVICE EASTERN REGION
STATE

Figure 9.